A first trustworthy records of the slugs of *Arion ater* complex (Gastropoda: Pulmonata: Arionidae) in central European part of Russia

Первые достоверные находки слизней из комплекса *Arion ater* в Европейской части России

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Abstract

Available data in the literature about presence of large slugs from the group *Arion ater* in Russia were confirmed in the early 2000s. Since the systematics and taxonomy of this group still remains unclear [Gural-Sverlova, Gural, 2011b], I refrain from concrete species designation of considered forms. Anatomically, they are most similar to the European *Arion vulgaris* Moquin-Tandon, 1855, but they are resembles a typical *Arion rufus* (Linnaeus, 1758) in many characters. The situation is complicated by the fact of hybridization between species of this group is established [Hagnell J., Schander C., von Proschwitz T., 2003]. Because anatomically examined samples in general are most similar to the species *A. vulgaris*; and, in addition, the life cycle of the considered slugs also corresponds to that of *A. vulgaris*, I named here considered slugs as *Arion* ex gr. *vulgaris*. Short description of the external and internal anatomy and life cycle are given. Possible ways of introduction are discussed here too.

A number of introduced species in malacofauna of Moscow region has been steadily increasing. This is facilitated by the growing economic and transport links with Western Europe, as well as notable climate change. A striking example of species whose range in the second half of the twentieth century increased significantly due anthropochore is European slug *Arion vulgaris* Moquin-Tandon, 1855. Species originally perhaps South-West France and Iberian Peninsula [von Proschwitz, Winge, 1994], which invaded many regions of Britain, Ireland to Sweden, Norway, Poland, Romania and Ukraine [Kerney, Cameron, 1979; von Proschwitz, 1989; von Proschwitz, Winge, 1994; Kozłowski, Kornobis, 1995; Gural-Sverlova, Gural 2011a; Păpureanu *et al*., 2014]. Species is almost indistinguishable from a closely related species like *Arion ater* & *lusitanicus* complexes by external morphology. Adult animals resemble a pale tan to dark brown or black forms of *Arion ater* or of *A. rufus* but often have a dark sole which contrasts strongly with a pale or reddish upper surface. Juveniles are banded and similar to those of *Arion rufus*. Also, differs from a real *A. lusitanicus* Mabille, 1868 (which is endemic species of Portugal, was not introduced to central Europe) in comparatively largest adult individuals. The name *A. lusitanicus* can no longer be applied to this taxon. In 1956 the invasive species was determined as *Arion lusitanicus* [Van Regteren Altena, 1956]. But that was a false determination, so the species known and feared as the Spanish slug in all of Europe, is not *A. lusitanicus.* A recent re-description of *A. lusitanicus* sensu Mabille, based on topotypes from Setúbal, Serra da Arrábida, Portugal [Castillejo, 1997] has shown that Portuguese *A. lusitanicus* has a very different spermatophore and internal morphology from the central and western European species to which this name was applied, first by Van Regteren Altena [1956] and then by subsequent authors. Falkner *et al*. [2002] have proposed that the north-western European species be called *A. vulgaris* Moquin-Tandon, 1855 as this is the first name which can be unambiguously applied [Anderson, 2005].

The *Arion ater*-complex is comprised of three species, *A. ater* (Linnaeus, 1758), *A. rufus* (Linnaeus, 1758) and *Arion vulgaris* Moquin-Tandon, 1855, which can be distinguished only by dissection of reproductive anatomy. These species generally characterized by comparatively short oviduct and large atrium. Presence of ligula is characteristic for complex. Color of the animal is not reliable for species determination of these two complexes. However, hybrids between *Arion ater* and *Arion vulgaris* have been reported by Hagnell *et al*. [2003]. Species of complex were introduced in many parts of Europe include Ukraine and Russia (Schileyko, 1982; Likharev, Wiktor, 1985; Gural-Sverlova, Gural, 2011a).

An absence of types for most described species complicate decision of problem. Specimens recently founded in Moscow and adjacent territories most similar to the species *A. vulgaris*. Determination of recently collected samples is confirmed by dissection. In the summer of 2010, several colonies of slugs looks like to *A. vulgaris* was found in Lviv, western Ukraine [Gural-Sverlova, Gural, 2011a; as *Arion lusitanicus*]. It was a most eastern area of the introducing of representative of this group.

There are many references on the presence of *Arion ater*-complex (as *ater, rufus* and *empiricorum*) on the territory of Russia in old literature [Georgi, 1800; Eichwald, 1830; Dvigubski, 1802, 1831; Kaleniczenko, 1851; Mel'gunov, 1892; Rosen, 1905]. Apparently, listed authors are determined species only by external characters of animals without anatomical research. By Simroth's opinion [Simroth, 1901], most of listed above authors has deal with large individuals of *Arion subfuscus* (Draparnaud, 1805). Probably, only two messages about findings of *Arion empiricorum* Ferussac, 1819 around Moscow can be accepted as trustworthy [Dvigubski, 1831, Rosen, 1905]. Only one finding of *Arion* ex gr. *vulgaris* in western Russia (Kaluga Region, near Fersikovo village, 39 km East of Kaluga) dated June, 1931 [Likharev, Wiktor, 1980: 395, as *Arion lusitanicus*] was confirmed by anatomical study. Other species of *Arion* could be confused for young *A. vulgaris* or *rufus*.

Three new trustworthy records of *Arion ater*-complex were registered in last years in Moscow City and Moscow region. Character of populations of the slugs in reviewed region (sporadic populations were found only in cultivated places) obviously indicates on the human factor in settling of the species. Detailed descriptions of these new localities with notes on morphology and biology of collected samples present below. Recent settling in new places outside of the native area of the species is discussed here. Here was established that the life span of Moscow's colonies of *A.* ex gr. *vulgaris* consists from 1.6 to 1.9 years. In contrary of *A. vulgaris,* life span of *A. rufus* consists of not more than of year.

Material examined

Reviewed populations were collected and examined in September – October 2012, May – October 2013 and May, 2014. During this period, the majority of mollusks reaches adulthood and the characteristic color, which together with the large size and embossed leather can reliably distinguish them visually from the smaller species of *Arion*, known from Moscow Region [Tappert, 2009]. Since there is a possibility of penetration of other large species of *Arion*, looks like *A. vulgaris,* for each population held fixation and dissection of the individuals. The main attention was paid to the form and proportions of distal parts of the reproductive system (atrium, oviduct). Early mentioning of the rare findings of this species and externally indistinguishable from the last of *Arion ater*-complex, however is not possible exactly determine what specific species were discussed.

Detailed descriptions of each of observed three populations (Fig. 1) are present below. Forest-park habitats of Moscow City were described by Tappert [2009]. For the preservation of studied materials was used method of "rigid" fixation [Likharev, Wiktor, 1985], wherein mollusks were placed in 75% ethanol. Dissection of the collected material produced in the laboratory of the Department of Invertebrate Zoology of Biological-Chemistry Faculty of the Moscow State Pedagogical University. Determination was carried out on the basis of morphological and anatomical (structure of distal parts of the reproductive system) characters. Next monographs and periodicals were used in the determination of [Kerney, Cameron, 1979; Likharev, Wiktor, 1980, Gural-Sverlova, Gural, 2011b].

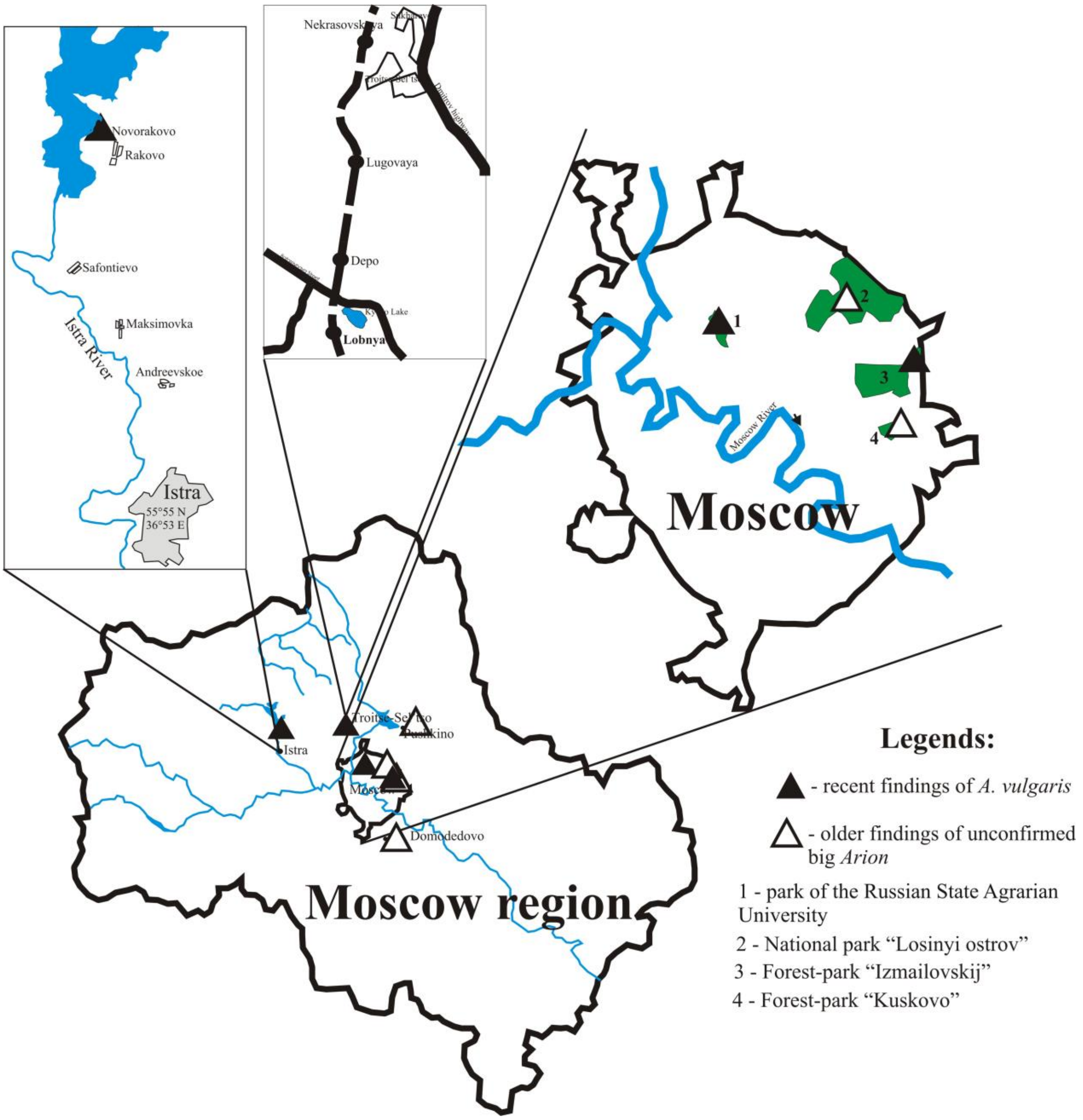

FIG. 1. Map of findings of the *Arion* ex gr. *vulgaris* in the Moscow region.

1. Moscow Region, Istra district, to N of Istra town, to NNE of Safotievo village, SE shore of Istrinskoe reservoir, Novorakovo village, 56°00’12”N, 36°50’33”E, personal garden of K.V. Makarov, 15-16.09.2012, coll: K. V. Makarov, 10 adult specimens (Fig. 2); 5-6.10.2013, coll: K.V. Makarov, 13 adult and subadult specimens.

First oral information about finding of “very large bright slugs” in kitchen-garden in Novorakovo village of Moscow region was received from K.V. Makarov in September of 2009. Later, in September of 2012, K.V. Makarov collected and passed me first 10 adult alive specimens of Arion vulgaris from his dacha in Novorakovo village. Collected slugs were very variously colored, from dark-gray to brown and brick-red. Extended length of these specimens varies from 80 to 95 mm. According to oral message of K.V. Makarov, slugs are lives only in gardens of the village and absent in adjacent forests. Furthermore, many of the adult alive specimens were collected in beginning of May of 2013 (Fig. 3). This finding suggests on prosperous surviving of winter period by individuals of the species, and prolongation of their life cycle up to one and half years. Interestingly, collected in May of 2013-2014 overwintered individuals had exceptionally dark (dark-brown to almost black) color of the body (Fig. 3). Numerous findings of egg clutches and young individuals of this species within at least the five last years showed a presence of stable population of *A.* ex gr. *vulgaris* in this locality. This population is characterized by a dense type of spreading of individuals.

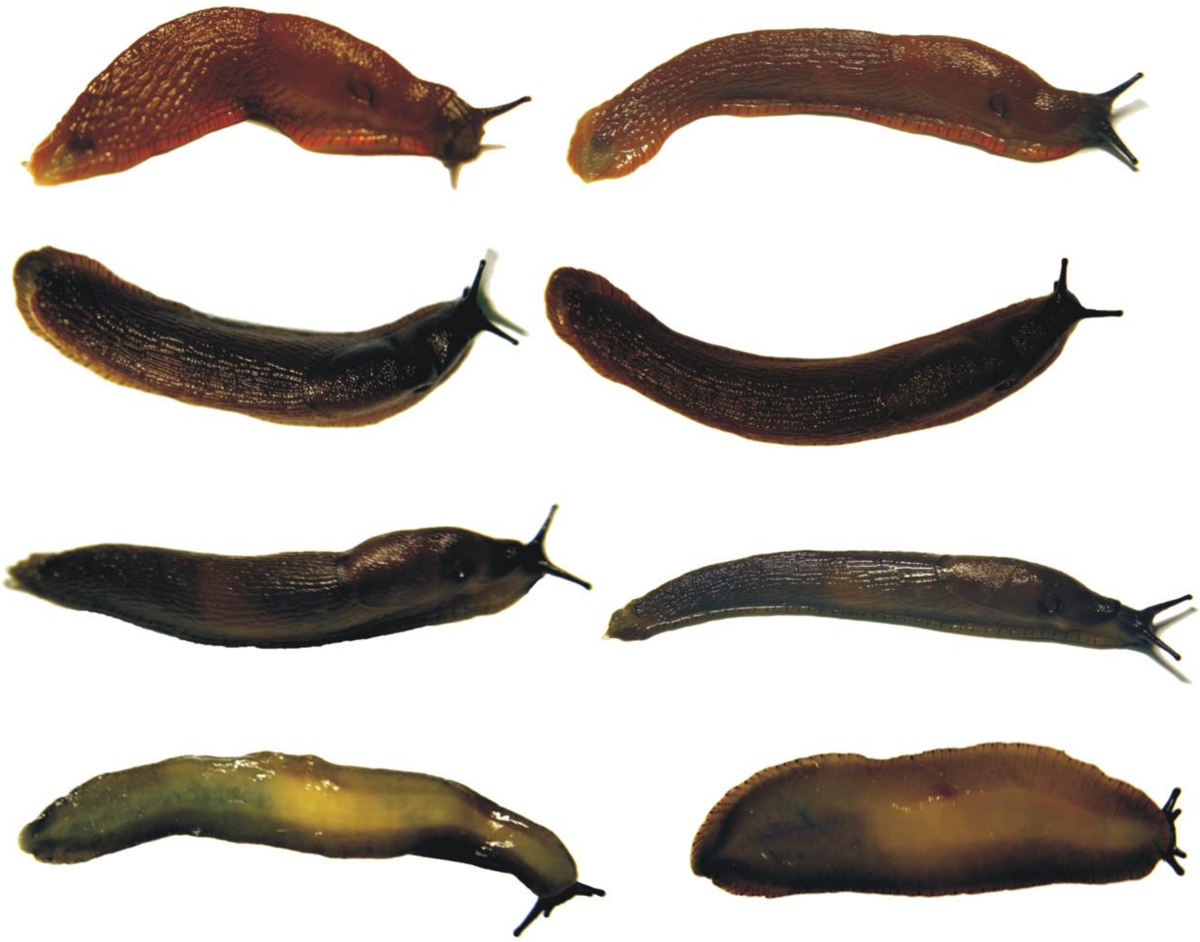

FIG. 2. Color variations of *Arion* ex gr. *vulgaris* from the Istrian population (Novorakovo village), September 2012. Photo by K.V. Makarov.

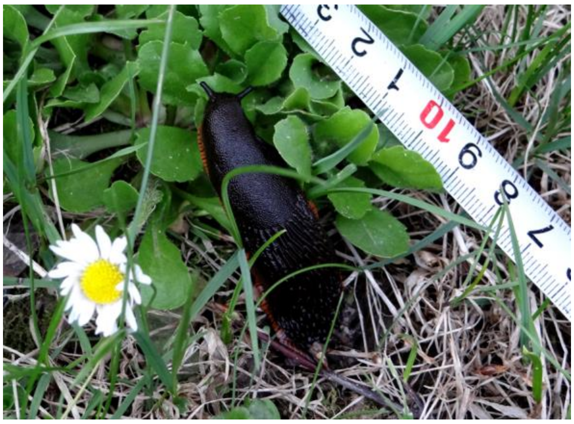

FIG. 3. Adult spring specimen of *Arion* ex gr. *vulgaris* from the Istrian population in natural habitat, May, 2013, photo by K. Makarov.

2. N of Moscow City, central part the park of the Russian State Agrarian University – Timiryazev's Agricultural Academy (TAA), left side of Pasechnaya street, 55°49'05"N, 37°33'10"E, 16.09.2012, 03.15 PM by Moscow time, on the tree between fence and road, cloudy

and rainy weather, data with photos from the message of A. Elez (Fig. 4). In addition, I collected 1 specimen in same locality in litter under piece of rotten linden's bark, 02.10.2012, 05.20 PM by Moscow time, t +15°C, coll/det: R.V. Egorov, in association with *Oxychilus draparnaudi, Arianta arbustorum, Deroceras caucasicum*, and *D. reticulatum* (Fig. 5).

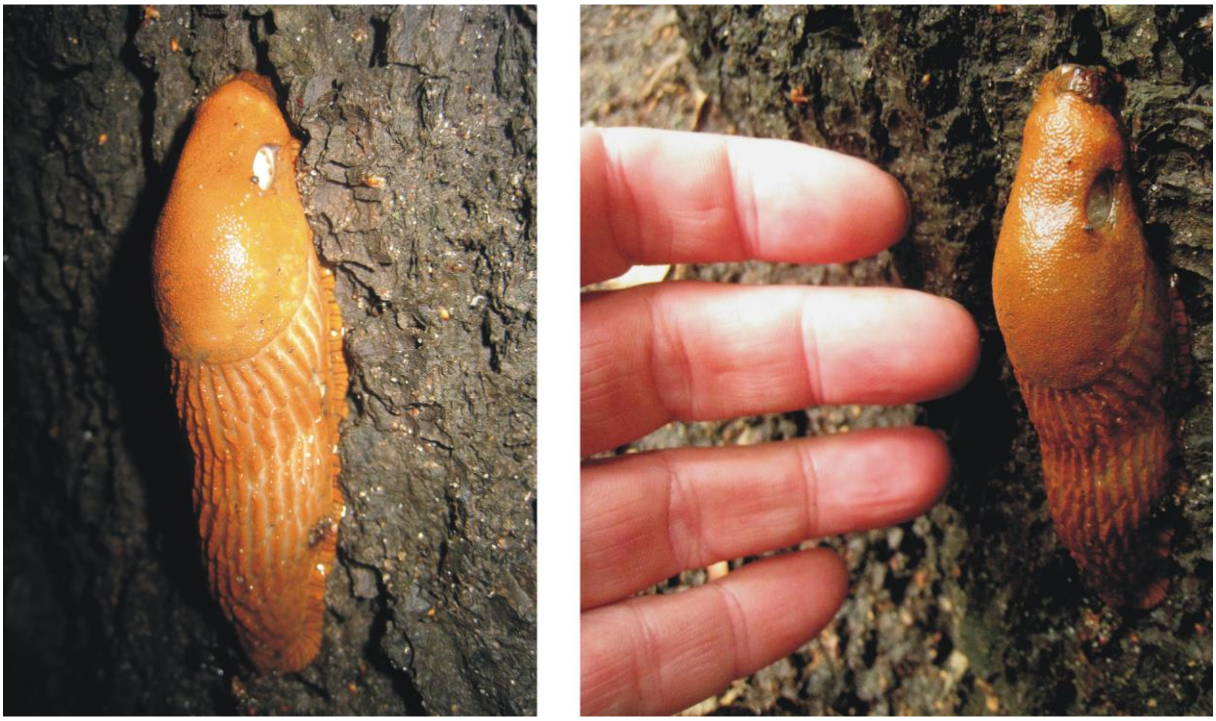

FIG. 4. *Arion* ex gr. *vulgaris* from the Timiryazev's Agricultural Academy (TAA). Photo by A. Elez.

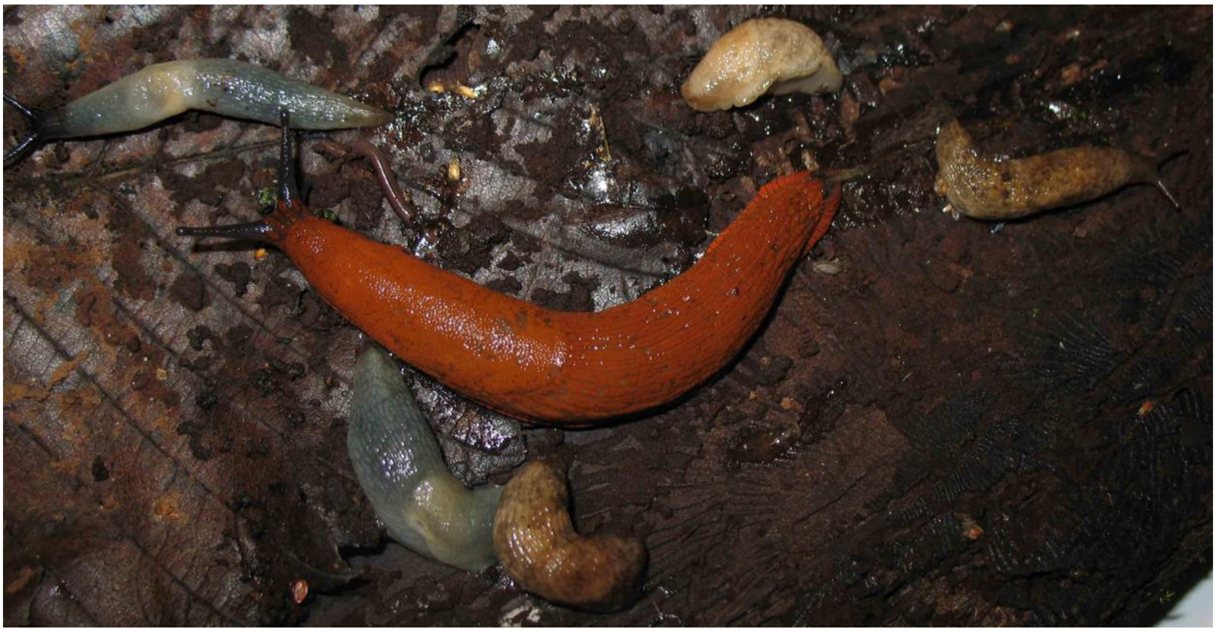

FIG. 5. *Arion* ex gr. *vulgaris* with associated species of slugs (*Deroceras caucasicum* (Simroth, 1901), *D. reticulatum* (O. F. Müller, 1774)) from the Timiryazev's Agricultural Academy (TAA), October 2012, photo by author.

A few specimens were collected in this locality in a first time for last years. However, by oral information from I. Melnik, he found similar large bright slugs in this locality early (in the mid to late nineties of last century). All collected specimens are brick-red with dark-gray tentacles and stripes on the head between tentacles. Specimens were collected in very wet and shady places along gutter near of fence of arboretum. This population is characterized by a random type of spreading of individuals.

3. E of Moscow City, Izmailovskij forest-park, 55°46’27”N, 37°44’54”E , ~ 50 m to SEE of 16th Parkovaya str., 2A, on edible mushroom (*Boletus* sp.) after night rain, 30.09.2012, 12–20 PM by Moscow time, t +13°C, coll/det: R.V. Egorov, 2 specimens (Fig. 6).

Two adult specimens were collected in north-eastern part of the Izmailovskij forest-park. Both specimens are dark-gray. This is a first record of the species in this locality. However, early the species *Arion rufus* was recorded in Kuskovskij forest-park which arranged southwards [Schileyko, 1982: 165]. Unfortunately, the sample is not saved and probably, it could be *A.* ex gr. *vulgaris*. Extended length of adult alive specimen exceed 105 mm. This population is characterized by a random type of spreading of individuals.

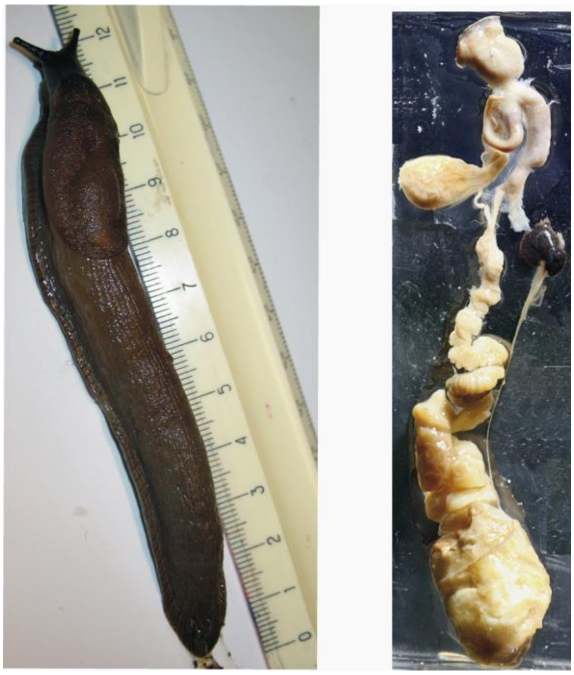

FIG. 6. *Arion* ex gr. *vulgaris* from the Izmailovskij forest-park. Left: alive sample; right: genitalia (slightly macerated). Photo by author.

Discussion

Coloring of studied live animals is extremely varied, depending on the color of the skin. In a sample of the Istrian population (Novorakovo village) dominated dark gray and brownish forms. Color of soles in the studied specimens of the same type, with light cream middle stripe and relatively dark edges. The edges of the soles of the darker, gradually brightening to the median strip. Light zone is about one-third the width of the sole.

Mucus from clear, colorless to slightly yellowish in different individuals, and the gray individuals colorless. Color of mucus was determined by applying a white paper to the back and mantle slug. Also, slugs were placed on a sheet of white paper and the color of mucus was determined by leaving traces. Thus, it was found that the mucus on the bottom of all the investigated specimens were colorless. There were studied 12 individuals from three localities .

After fixation and removal from the body much of mucus animals get a grayish or brownish color.

Opaque, white eggs are laid in groups of 27–44 in shady moist places, such as under barks, stones or boards and in plant litter. Eggs are 3–4 mm in diameter. Eggs are observed and counted in natural habitat in TAA and in laboratory conditions in October, 2012. Also, additional laying were observed in September-October of 2013 from Novorakovo village (Fig. 7). Some laying were laid in laboratory in October, 2013.

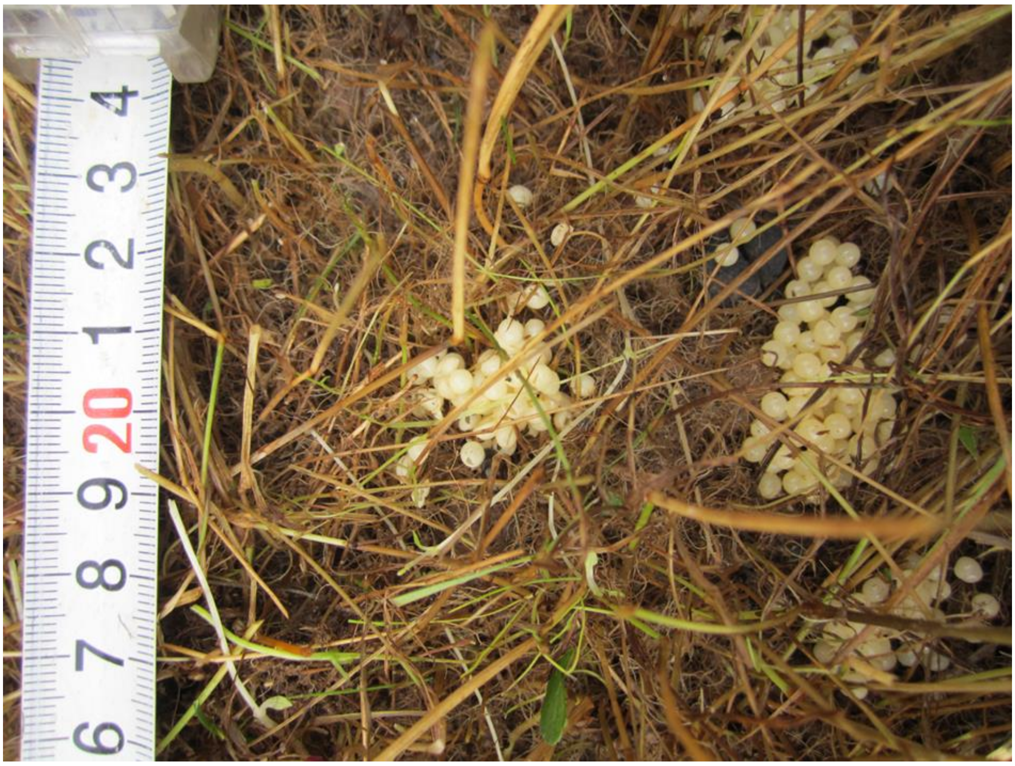

FIG. 7. Laying of *Arion* ex gr. *vulgaris* from the Istrian population (Novorakovo village), September, 10th, 2013. Photo by K.V. Makarov.

External structure of the distal parts of the reproductive system in the studied slugs (Figs. 6, 8) is typical for representatives of *A. ater*-complex. The atrium is relatively large, assymmetrical, the oviduct is clearly divided into two sections: frontal part is widened, back part is narrower. Both parts are almost equal in length or back part is slightly longer than the frontal. However, the relative length and width of the front part of the oviduct is a character, not only prone to considerable variability even within a single colony of the species, but also a change in the process of growth and development of slugs [Sverlova, Gural, 2011]. There is a massive ligula inside the extended part of the oviduct, the frontal end of which comes into the atrium (Fig. 8B). Epiphallus flows into the atrium above the seminal receptacle duct and the oviduct, with the confluence of the three organs in the atrium can be placed almost in a straight line in preserved material (Fig. 6).

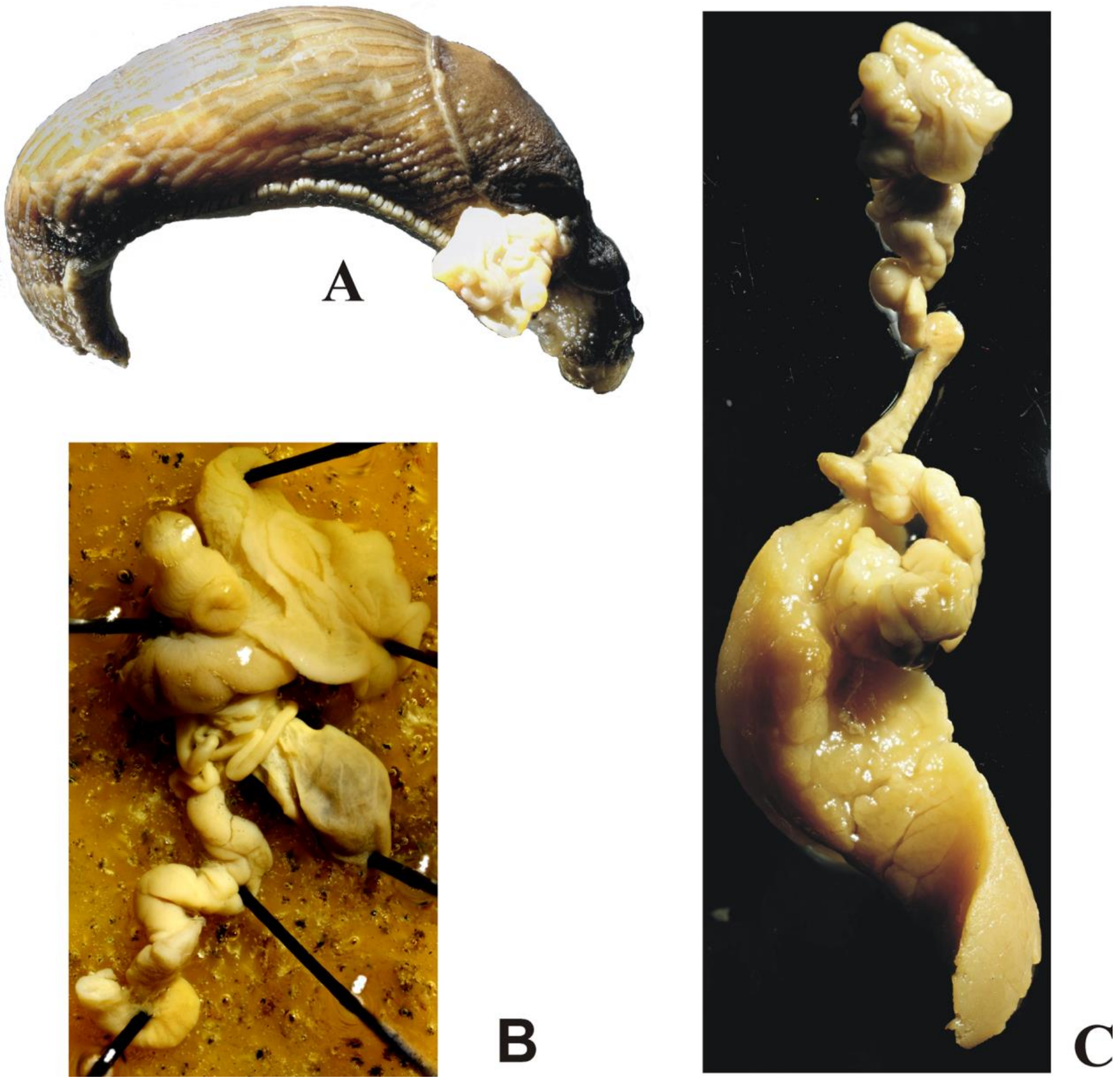

FIG. 8. *Arion* ex gr. *vulgaris* from the Istrian population (Novorakovo village): A: preserved specimen with turned outside ligula; B: distal part of genitalia with partly dissected ligula; C: genitalia; photo by author.

Except listed above, there are three findings of large bright slugs published early: E Moscow, Kuskovo [Schileyko, 1982: 165, as *Arion rufus*], Moscow Region, Pushkino district, Kostino village [Schileyko, 1982: 165, as *A. rufus*], NW Russia, S Kareliya, 55 km to N of Petrozavodsk, Kondopoga district, near of Sandal Lake [Kantor, Sysoev, 2005: 285, as *A. rufus*]. Unfortunately, place of storage of these samples is unknown. In correspond to message of curator of malacological collection of the ZMMU A. Sysoev, “(sample) is not listed in the database and not presented in the collection”. Also, there is unchecked information on presence of similar slugs in the National park “Losinyi ostrov” in north-eastern part of Moscow.

And, in summer 2013 large colony of *A.* ex gr. *vulgaris* was found in the vicinity of “Nekrasovskaya” railway platform (Troitse-Sel’tso village, about 10 km to North of “Lobnya” railway station, Fig. 9) to the North of Moscow, in Mytitschee district. By oral message of A.V. Matalin, slugs are lives in field, overgrown alfalfa and not found in plots and gardens of village. In addition, according to unverified information, the colony of similar slugs was found in the Domodedovo district to the South of Moscow in autumn of 2012. All these findings indicate that the distribution of a slug of *A.* ex gr. *vulgaris* happens everywhere in the vicinity of Moscow at a very fast pace.

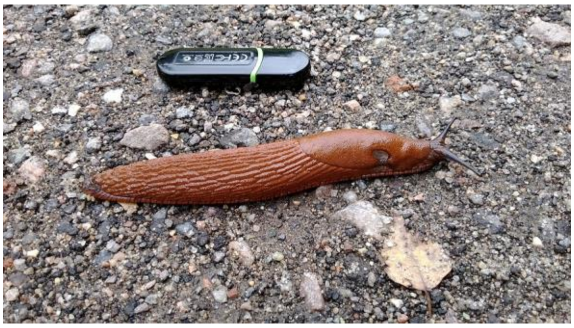

FIG. 9. *Arion* ex gr. *vulgaris* from the vicinity of Troitsa-Sel'tsy village, Mytitschee district of the Moscow region, August, 2013. Photo by A.V. Matalin.

Primary population in Moscow and Moscow region can be considered a colony in the park of the TAA. According to oral messages of a number of persons, arboretum of the TAA imported seedlings of different tree and shrub species with the soil from Eastern Europe since the Soviet period. Recently (according to botanists from the TAA), arboretum of the Academy imported seedlings of ornamental trees and shrubs (arborvitae, juniper, etc.) from the Czech Republic and Germany in 1992–1995. Seedlings of these plants are often sold in pots filled by peat-grit or similar soil mixture. It is very convenient to transport and planting, but can lead to skidding on various pests for the site, at least at some stage of their life cycle associated with the ground. In this way, population of *A.* ex gr. *vulgaris* was founded in the Istra district (Novorakovo village). In correspond to oral message of K.V. Makarov, some of the financially well-off villagers planted of the arborvitae alley seedlings for which acquired in the TAA. The origin of other populations of slugs probably also associated with artificial planting, imported from Europe in the different years of the last century. This is supported by the fact that all known populations of slugs are narrowly localized, and are located in places, one way or another related to human activities.

Barriers to their self-settlement may be wide streets. Individuals of *A.* ex gr. *vulgaris* can develop significant for land snail speed, according to my personal observations about 10–14 cm per minute, which is the maximum travel distance of up to 6–8.4 m per hour (continuous motion). So in theory they could overcome such anthropogenic barriers at night or during wet periods. However, slugs, like other species of terrestrial mollusks, avoid large areas of hard surface and no fragments of vegetation, even grass. Staying in such areas is a risk of drying for slug. The narrow asphalt roads or footways is not a barrier for many slugs and large snails [Sverlova, 2002]. On the contrary, they are used clams at night, in the morning and even day during or after rains. According to observations of A.V. Matalin in Troitse-Sel'tso village, the slugs have not yet spread to the other side of the Dmitrov highway, passing through the village.

Some anthropochore mollusks can avoid not only forest habitats [Shikov, 1979], but large "forest-like" areas in city gardens and forest-parks [Sverlova, Kirpan, 2004]. This explains the lack of slugs in the forest near Novorakovo village. On the other hand, in the park of TAA registered several commensal molluscs (*Oxychilus draparnaudi, O. alliarius, Arianta arbustorum, Helix pomatia, Deroceras caucasicum*), and the presence of streams and ravines creates favorable microclimatic conditions for land mollusks. It appears that urban habitats may harbour a slug fauna which, with respect to the number of species, is richer than that of open anthropogenic habitats, such as cultivated fields [Sionek, Kozłowski, 1999].

On the basis of analysis of the present vegetation, topography and human activities park of the TAA can be characterized as a very favorable area for the development of colonies of *A*. ex gr. *vulgaris* and further distribution in the parks of Moscow and Moscow region. Thus, taking into account the general warming of the climate, quick speed of reproduction and dispersal of discussed slug it should expect to find its new populations in the central European part of Russia in the coming years. It should also be noted that in the future this species can of competing native species of slugs, as is settled until exclusively in anthropogenous biotopes traditionally occupied representatives of the genera *Arion*, *Deroceras* and *Agriolimax*. Also discussed species is one of the most important invasive species in Europe, affecting both biodiversity and agriculture. The species is spreading in many parts of Europe causing severe damages to horticultural plants and cultivated crops in agriculture since satisfying and effective management solutions are still lacking. Some my personal observations in a terrarium revealed features of their nutrition. Slugs are actively ate potato tubers, cucumbers, carrots and apples, preferring them to the leaves of lettuce and cabbage (Fig. 3 B). Regarding the biological control, microscopic nematode *Phasmarhabditis hermaphrodita* (A. Schneider, 1859) is the only commercially developed agent [Pechova, Foltan, 2008]. Carabid beetles, especially *Carabus nemoralis* O. F. Müller, 1764 and *Pterostichus melanarius* Illiger, 1798, have been shown to control densities of *A*. ex gr. *vulgaris*, as juveniles and eggs, when population is larger in recruitments and more vulnerable. Moreover, natural conditions for predation in the field are confirmed by data from the field sampling [Pianezzola *et al*., 2011], making these carabid beetles species good candidates as biological control agents.

This review summarized the current distribution of this invasive slug species in Russia and portrays a potential further distribution. Thus the study may be regarded as a baseline for future studies in terms of the most important in explaining the distribution and hence give a more accurate understanding of the factors that allow this invasive species to spread.

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